

GENERAL SETTING AND PHYSIOGRAPHY The Ismenius Lacus quadrangle includes the northernmost extension of the cratered high-

lands that occupy a major part of the southern martian hemisphere. It includes three prominent physiographic provinces: cratered highlands in the south, relatively featureless plains in the middle, and mottled plains in the north. The highlands are separated from the plains by a belt of dissected terrain, containing mesas and buttes ("fretted terrain" of Sharp, The highlands are subdivided into six intergradational map units: a hilly and cratered material around old, large craters and crater clusters; a hilly plains material of irregular topography dominating the eastern highlands; a ridged plains material adjoining the hilly plains to the southeast; a cratered plains material consisting of a smoother cratered plains unit dominating the western highlands; a plateau material along the northern highland margin, and a knobby plains material occurring inside old basins and craters. The highlands are traversed by flat-floored valleys, which form integrated patterns and widen northward towards the highland border. The eastern highland margin is cut by parallel grooves. Northward, beyond the edge of the highlands, lies the dissected belt that contains mesas, isolated mountains with sharp crests (unit k), and areas characterized by hummocky material. The plains material and mottled plains material of the northern map area are seen through haze

The southern region of the plateau has a moderate to high density of craters larger than 20 km (15-35 percent of surface area, Soderblom and others, 1974). The northern border region of the plateau is less densely cratered (5-15 percent) and the northern plains have a low crater density (less than 5 percent). Contours on the map show that the entire region slopes gently from 4 km elevation in the southeast to -2 km in the northwest. Detailed, approximately north-south-trending topographic profiles (Barth and others, 1974), however, show the plateau to gently rise towards the northern scarp, where it abruptly drops 1.5-2 km. Relief on the plateau surface is on the order of 0.5 km, and scarps on valleys measure 0.5-1 km.

DISCUSSION OF UNITS

The oldest recognized highland material of the map area is the hilly and cratered material. It is found predominantly around old, large craters and crater clusters and probably consists of overlapping old crater rims and crater ejecta. The hilly and cratered unit may be buried locally by a mantle of thin plateau-forming material or windblown sand and dust, as suggested by its subdued appearance and intergradational contact with adjacent plains units. The hilly plains material is transitional with the hilly and cratered material and occupies the terrain between large, old crater clusters. It partially buries craters of c₁, and most c₂ age, whereas craters of c_3 age are superposed, implying that hilly plains are older than craters of c_3 age. Three alternative hypotheses can be advanced for the origin of the hilly plains material: (1) It may be composed of thin volcanic flows covering buried stacks of overlapping crater ejecta that are similar to those of the lunar highlands. Flow lobes, wrinkle ridges, and buried craters like those seen on lunar maria support a volcanic origin. (2) It may be composed of thick, viscous volcanic material that completely buries the underlying topography and may have an intrinsically hilly surface. (3) It may be composed of volcanic material that belongs to an early stage of planetary development when the crust was still hot and had little strength: if this stage lasted through the time of intense bombardment, early craters formed during this stage may have been completely obliterated and formed hilly plains. Old, flat-floored, rimless craters that occur on these old highland plains and that are unlike most craters seen on the Moon could be explained by a combination of gravitational adjustment through dropping of rims and raising of floors and partial burial; thick flow lobes cascading into crater interiors support burial by volcanic material. Thin mantling by sand or dust may be present locally. The ridged plains material is similar to the hilly plains material, but intercrater areas are slightly smoother, and prominent ridges and scarps traverse the surface in a northwesterly

direction. The ridges and scarps, when seen on high-resolution frames, resemble lunar mare ridges. The origin of the martian features is controversial, as is that of the lunar ones, for which both structural adjustment resulting in crumpling of the surface (Howard and Muehlberger, 1973) and a combination of volcanic intrusions and extrusions along structures (Young and others, 1973) have been proposed. The martian ridges, however, have enhanced relief resembling erosional etching that suggests modification by wind. The origin of the unit is inferred to be similar to that of the hilly plains unit. The cratered plains material is similar to the hilly plains material in crater density and age

of superposed and partially buried craters. Its distinguishing characteristic is a flat surface, locally accentuated by dark mottling inside and outside many rimless craters. Wrinkle ridges, which were not mapped but are visible at high resolution, suggest a volcanic origin. The flatness of the cratered plains may result from an underlying smooth topography, or from less viscous lava than that of the hilly plains. Erosional leveling is considered a less likely alternative, as wrinkle ridges retain sharp relief. The age of this unit is thought to be similar to that of the hilly plains material.

The plateau material that forms the northern border of the highlands is less cratered than the highland units farther south, and its contacts are ill defined. High-resolution pictures show fresh-looking lobate scarps that may be flow fronts. The low crater density suggests a relatively young age for the unit, but the superposition of some c3 craters restricts its emplacement to before the end of c₃ time, similar to highland units farther south. The lack of

old craters may result from complete burial of craters of c₁ and c₂ age, whereas these craters are only partially flooded on the other units. North of the boundary escarpment separating uplands and lowlands the plateau unit becomes highly dissected and forms mesas of the so-called "fretted terrain." The mesas are commonly flat topped and are bounded by straight or curving scarps that intersect at sharp angles. The mesas are erosional as shown by the complete transition of intermesa lows and valley floors that belong to clearly erosional valley systems. The erosion appears to have favored lines of weakness resulting from linear structural systems, represented by the grabens near the northeast boundary of the highlands, and curved traces of buried craters. as seen in several large semi-circular reentrants into the plateau. These large arcuate scarps show that many more craters may be buried below the plateau units than are visible on the surface. Some craters of c₃ age appear to be breached by erosion, others, are superposed

The knobby plateau material occupies the central part of a circular feature near the north edge of the plateau and crater interiors near the west edge of the map area. The circular feature is probably a buried basin whose surface shows incipient erosional dissection. The basin structure is evident in concentric grooves and an inward facing escarpment surrounding the structure on its south side. The unit is similar to chaotic materials in the Oxia Palus and Margaritifer Sinus quadrangles that likewise tend to have circular boundaries. The preferred localization of this unit inside craters and basins suggests that the crater and basin interiors, even after burial, are less resistant to erosion than intercrater areas. The unit is thought to be composed of the same material as the other plateau units but differs by being incipiently eroded. The erosion took place near the middle of c_3 time.

Knobby material occurs between mesas and beyond the northeast edge of the plateau. The mountains forming the knobs occur among and are transitional with mesas. They form where erosion advanced to destroy the flat top of the mesas completely, leaving a cone or sharp-crested ridge. Many knobs north of the highland border are alined to form vague circular structures, which suggests that they may be erosional remnants of former buried craters. Some knobs, however, project above the plateau surface and are probably remnants of old crater rims that were never buried by lava. Greater abundance of knobs in the eastern map area may result from poor resistance to erosion of the highland units (cratered and hilly plains) near that area. There the stratigraphic section may consist of a thin volcanic caprock over a thick section of easily eroded crater ejecta, whereas a thick lava section may be present farther west where the mesa-forming smooth plateau unit occurs more extensively. Alternatively, greater structural disturbance may have resulted in knobs through more intricate erosional dissection. Knobs are considered to have a stratigraphic age similar to that of the highland units from which they are derived, and they acquired their erosional shape during the time of general dissection of the area. Facets on the cones suggest possible modification by wind action (Gipson and Ablordeppey, 1974). The hummocky material is dispersed among the knobby material in the plains below the plateau escarpment. The size range of the hills of the hummocky material is generally

discrete from that of the mountains of the knobby material, suggesting different origin. The hummocky material may consist predominantly of material from the lower part of the stratigraphic section of the plateau, which may be mostly crater debris. Additionally, a sizable part of the hummocky material may be mass wasting products from adjacent scarps and from mountains that were completely obliterated. The unit therefore has an old Channel deposits form the floor of sinuous valleys that widen toward the north and gradually merge with the northern plains. Channel floor deposits also occupy the floors of linear grooves along the northeast edge of the plateau. These grooves are grabens or joints enhanced by erosion that may have been particularly effective along the steep gradient near the plateau margin. The sinuous valleys are generally flat floored and bordered by steep scarps. Locally they widen along arcuate scarps that are probably the rims of excavated craters. The valleys merge downslope to form integrated systems. Tributaries begin abruptly with amphitheater valley heads or begin gradually with incised sinuous grooves, and they increase in depth toward their mouths where they merge with the trunk valley at base level. This suggests formation by water. The valleys may have become enlarged later by lateral recession of the walls. Valleys are locally buried by c3 crater ejecta and thus data from the same erosional interval that affected the general area. The deposits on the floor of the valleys, however, appear young, as they are smooth and featureless and have few craters superposed. Like some of the plains deposits, they are probably laid down by wind. Channel material is thus not composed of the original alluvium, but of an eolian cover on the alluvium or eroded plateau units.

Plains material covers the terrain of the north half of the map area, which appears sparsely cratered and nearly featureless on Mariner images. As the ground is obscured by clouds and haze on the images, much topographic detail may be undetected. Plains material also occurs in craters on the highlands, especially in craters of c₃ and younger age. Plains and channel materials are transitional in many places, and the boundary is arbitrarily drawn where a channel shape is no longer present. On high-resolution pictures crater ejecta are bounded by scarps, suggesting presence of an easily eroded deposit on the plains and active deflation (Arvison and others, 1976). On other high-resolution pictures structures like lunar mare ridges are seen, suggesting that the plains unit may be composed locally of volcanic material. The deposit probably consists of two major components, 1) relatively young lava flows flooding the plateau margin, and 2) eolian sediments interbedded with and overlying volcanic and alluvial units that occur near the channel mouths. Craters on the northern plains are of two types: sharp-rimmed craters filled to nearly the same level on the inside and outside, and sharp-rimmed, nearly bowl-shaped craters with dark spots in the interior. The filled craters occur predominantly below the plateau edge, and examination of high resolution frames suggests that at least some are exhumed crater rims. The bowl-shaped craters are of c₂ age or younger, and no old craters are observed, which indicates a late c₃ age for the plains unit. The uppermost eolian sediments may be recent. The mottled plains material in the northernmost part of the map area is covered by haze. and surface detail is obscured. Craters that are easily visible are similar in their characteristics and density to c₂ craters of the plains unit to its south. Vague, circular, light-colored spots

may be old, flooded, and possibly eroded craters. High-resolution pictures show evenly spaced, sharp hummocks and some pedestal craters (Arvidson and others, 1976), suggesting that wind erosion may have been severe. The unit may contain material similar to the plains unit but have different albedo, or may consist of several unidentified units. Many old craters (unit c₁) occur on the highland materials, but only those with raised rims have been mapped as material units. Most old craters are nearly rimless, have flooded interiors, and are shown with rimcrest symbols. Somewhat younger craters (unit c2) are

similar to c1 craters but have deeper interiors, and more craters of this age have well-defined rims. Both c₁ and c₂ craters precede the final emplacement of the highland units, as they are partly buried. Young craters have raised rims and ejecta blankets. They are superposed on the highland units, and in places both craters and highlands are breached by erosion. They are also superposed on the plains unit in the lowlands whose emplacement follows the breaching of the highland units. Therefore, both the dissection of the map area into valleys and mesas and the emplacement of most of the northern plains materials took place during The large crater Lyot in the center of the map area is of c3 age or younger. It has an

extensive radial ejecta blanket and secondary craters visible on high-resolution pictures. Secondary craters can be recognized on low-resolution pictures around crater Cerulli, which has been assigned a c₄ age. The secondary crater chains are straight and occur both on top of and beyond the continuous ejecta. GEOLOGIC HISTORY A high crater flux in early martian history caused formation of many overlapping craters

and basins similar to the highlands of the Moon. Later outpourings of large volumes of lava buried most of the old cratered surface and created the highland units. Alternatively, isostatic adjustment and early volcanism of a youthful and active martian crust may have eradicated many craters of the early heavy cratering flux and created the rimless craters and extensive intercrater plains now seen on the highland surfaces. After formation of the highlands, craters of c3 age were superposed. Then a period of erosion ensued, some fluid material, probably water, carved out canyons and valleys, and the highlands became dissected into mesas and buttes. The dissection proceeded along linear structural trends, which resulted in straight scarps and grooves, and curved trends, which follow the structural imprint of buried craters. The present northern margin of the highlands developed a large escarpment during this time. How far the exposed part of the highland units extended beyond this escarpment before erosion is not known, but at least 500 km is indicated by the dissected belt. After the major dissection was completed, scarps bounding valleys and mesas continued to retreat laterally by mass wasting and possibly wind erosion. A period of young volcanism that began during c₃ time flooded parts of the northern smooth plains and the dissected highland area, and wind deposited sheets of sand and dust on the smooth plains, valleys, inter-mesa lows, and in the deep interiors of young craters. An interplay of wind deflation and deposition continues to the present.

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